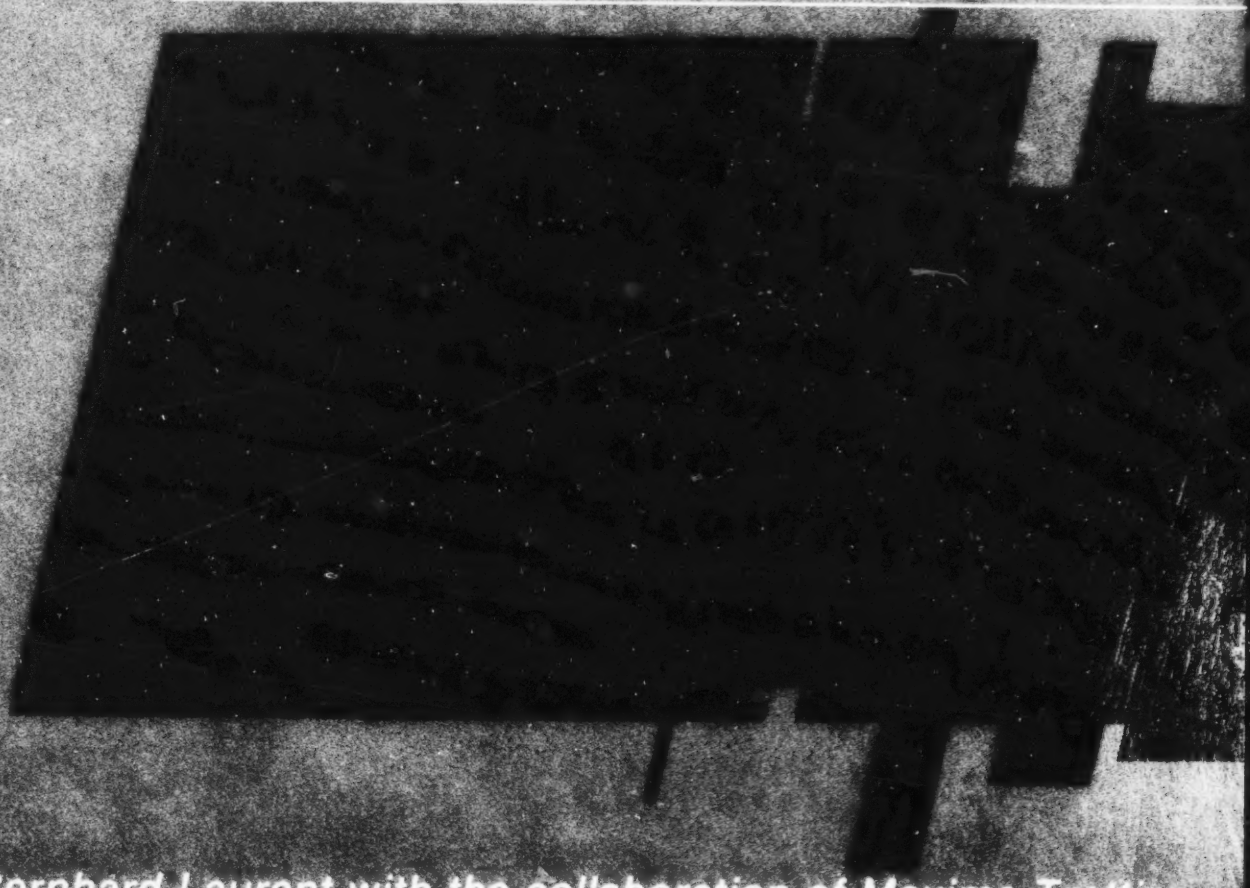
HEALTH

SITUATION REPORT



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ASBESTOS AND HEALTH

Situation Report

ERRATUM

The fifth paragraph on page 18, which reads "The most common types of mesothelioma... into the subjacent tissues", should follow the fourth paragraph on page 20.

Prepared by: Service de l'économie minérale

The authors wish to thank the organizations and companies which authorized them to utilize some of their photographs to illustrate the present document.

FOREWORD

During the 1970's, increased concern about environmental protection, especially as it related to the workplace, focused mainly on the dangers stemming from the uncontrolled use of asbestos. This resulted in a negative public attitude towards this substance which, in turn, led manufacturers of asbestos products to search for substitutes. Furthermore, many governments either adopted strict regulations concerning the use of asbestos, or are about to do so.

Faced with this situation, the Service de l'Économie minérale (S.E.M.) of the ministère de l'Énergie et des Ressources, felt that it was necessary to summarize the latest data available on the effects of asbestos on health.

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GLOSSARY

I – Mineralogical

- **attapulgite:** variety of magnesium rich clays frequently found in fibrous form.
- **wollastonite:** type of fibrous silicate, rich in calcium, which replaces asbestos in some applications.
- **zeolite:** extensive family of aluminosilicate minerals. Zeolites may be found in fibrous form such as erionite and natrolite.

II – Physico-chemical

- **adsorption:** retention of particles, molecules or atoms, on a solid surface.
- **fibre:** particle whose length widely exceeds the diameter. In the case of asbestos, the inhalable fibre is defined as having a length greater than 5 microns and a diameter inferior to 3 microns. In Canada and some other countries, the length/diameter ratio must be ⅓ for this definition to apply. A microfibril is a fibre whose dimensions are such that they are only visible under a microscope.
- **pH:** hydrogen ion potential of an aqueous solution. Acid solutions have a low pH whereas alcaline solutions have a high pH.
- **phosphorylation:** chemical reaction leading to the addition of the phosphate grouping (PO_4^{-3}).
- **ponderal:** related to weight.

III – Biological and Medical

- **bronchial carcinoma:** type of cancer which develops in the bronchi.
- **carcinogen:** substance which may induce cancer.
- **collagen:** protein which provides a certain rigidity to the support tissues.
- **fibrogenic:** which induces the development of a fibrosis.
- **homeostasis:** stabilization of physiological conditions.
- **hyperendemic:** refers to an area where a disease is very prominent and chronic.
- **immunologic:** refers to the defence mechanisms of living organisms.
- **implicit rate:** rate of cases which arise in an identified sub-group.
- **incidence:** number of new cases of a disease in a population during a specific period of time.
- **interstitial:** located in the spaces surrounding cells and tissues.
- **latency:** delay between a stimulation and its response.
- **lytic:** relative to the destruction of cells and tissues.
- **neoplasm:** cancerous tumor.
- **nicotinism:** series of symptoms resulting from the use of tobacco.
- **nodule:** small rounded lump.
- **pericardium:** heart envelope.
- **peritoneal:** relative to the peritoneum.

- **peritoneum:** membrane which lines the abdominal cavity and covers the organs of the digestive system.

- **plethysmograph:** apparatus which permits controlled respiration.

- **pleura:** pulmonary envelope; the parietal pleura is adjacent to the ribs whereas the visceral pleura is located near the diaphragm which closes the rib cage.

- **pleural:** relative to the pleura.

- **pneumoconiosis:** respiratory disease caused by the industrial environment; for example, silicosis among workers exposed to silica, asbestosis, etc.

- **prevalence:** total number of cases (old and new) in a population during a specific period of time.

- **pulmonary alveoli:** tiny sacks at the extremity of the bronchial tubes in which gaseous exchanges occur.

- **pulmonary fibrosis:** gradual replacement of pulmonary tissue, which has a certain flexibility, with collagen, with a resulting loss of elasticity.

- **pulmonary sarcoidosis:** pulmonary affection of uncertain origin leading to fibrosis.

SUMMARY

Asbestosis, a typical disorder affecting asbestos workers, develops following heavy and prolonged exposure to asbestos fibres released by the various extraction and manufacturing processes. It is characterized by a pulmonary reaction leading to fibrosis, which in turn can induce the development of cancer.

Besides restraining the individual's functional capability, asbestosis increases the probability of lung cancer occurrence (about 2,8 times more than among the normal population). Smoking greatly increases this probability to the extent that the tobacco-asbestos combination constitutes a risk about 10 times greater than asbestos alone and about 5 times greater than tobacco alone.

The asbestos-asbestosis-cancer association occurs over a very long period of time (20 to 30 years). Asbestosis cases presently under observation are due to previous exposure in an era when poor health conditions, outdated by present day standards, prevailed. An abnormally high prevalence was thus recorded, beginning at the end of the '60s. However, data related to recent years (1976-1982) seem to point at the disappearance of the phenomenon.

Recently, mesothelioma has been associated with asbestos and some authors tried to attribute most cases to this mineral. However, asbestos does not constitute the sole cause of mesothelioma, since fibres as diverse as attapulgite, wollastonite, zeolites, rock wool and certain synthetic fibres can also trigger it. On the other hand, some types of mesothelioma (more than a third) have nothing to do with asbestos exposure.

If epidemiological studies at the mines and mills show an excess of cancer cases, they imply that other industries could present a greater risk. However, it is rather difficult to quantify this risk since most studies do not explicitly state the exact amount of asbestos the workers have been exposed to. The few studies where dust concentrations were measured are difficult to compare.

Methodology, hypotheses relating to the level of dust concentration, the period of exposure and the length of follow-up are important factors which must be taken into account before making comparisons. No general study has really taken these elements into consideration to produce an actual model showing the relationship between exposure to asbestos and a risk value for levels of exposure lower than 10 fibres per cubic centimetre. Neglecting these factors while establishing patterns taints every conclusion concerning the risks incurred at low dose with such a high error probability that these patterns are difficult to justify.

The results of recent studies, however, tend to suggest the possibility of the existence of a threshold, below which asbestos can no longer induce any physiological effect.

Radical changes brought about in the extraction as well as in the manufacturing industry have considerably reduced exposure rates. These reduced rates and the elimination of asbestos products likely to release fibres demonstrate a positive evolution towards controlling undesirable effects.

Moreover, the implementation of systematic detection practices and the improvement of diagnostic criteria warrant the assumption that the probability of an outbreak of cancer due to asbestosis will become non existent.

INTRODUCTION

The appearance of the first form of life on earth, which led to the birth of the human race, represented a radical change in the evolution of events. In fact, for the first time, part of the energy released was to be diverted in order to maintain a dynamic balance between a relatively stable environment and a changing one. Since then, the burden of homeostasis, a major constraint of living systems, rests on the ability of the system to adapt to its environment.

The human society represents a summit as far as the organization of life is concerned since man, endowed with the power of apprehension, can not only understand his environment and therefore better adapt to it, but he can also modify it by using his ingenuity.

However, the price of the continuing quest for improvement is the emergence of undesirable and often unpredictable epiphenomena. Thus the great exploration voyages and the first commercial ventures brought the plague which decimated Europe. The emergence of the industrial era aggravated the poor sanitary conditions by concentrating populations. And closer to home, the advancement of medical science led to synthesizing heroin which, despite its remarkable and indeed unsurpassed analgesic properties, caused the development of problems of unsuspected magnitude.

All these secondary effects are related to the uncertainty which exists between two inevitable realities: birth and death. Only the improvement in the level of knowledge can mitigate, at least in part, the risk caused by uncertainty.

Tragedies which accompany progressive advancement seem practically inevitable at the outset. Fortunately, however, the resurgence of scientific and political interest which they provoke completes the knowledge acquired, making it possible, through improved risk evaluation, to maximize the benefits derived from a particular discovery.

Asbestos, or rather the use of asbestos, represents one of those situations in which detection of associated problems was only made following a major expansion in its use.

In retrospect, it is possible to establish to what extent a number of factors contributed to the emergence of the first strong manifestations during the 1960's, which indicated that asbestos presented certain health risks and that more intensive epidemiological studies were needed.

The long latency period between the appearance of clinical signs and the beginning of exposure, the duration and level of exposure, the type of asbestos, the personal evaluation by the workers regarding their state of health and the available medical tools, all played a definite part from a socio-toxical point of view. Industrial expansion, politico-economical upheavals and labour instability caused additional obscurity to the extent that it was necessary to await stabilization, or at least a non-anarchistic evolution of these factors, to see signs of the possibility of an association between respiratory problems and exposure to asbestos dust.

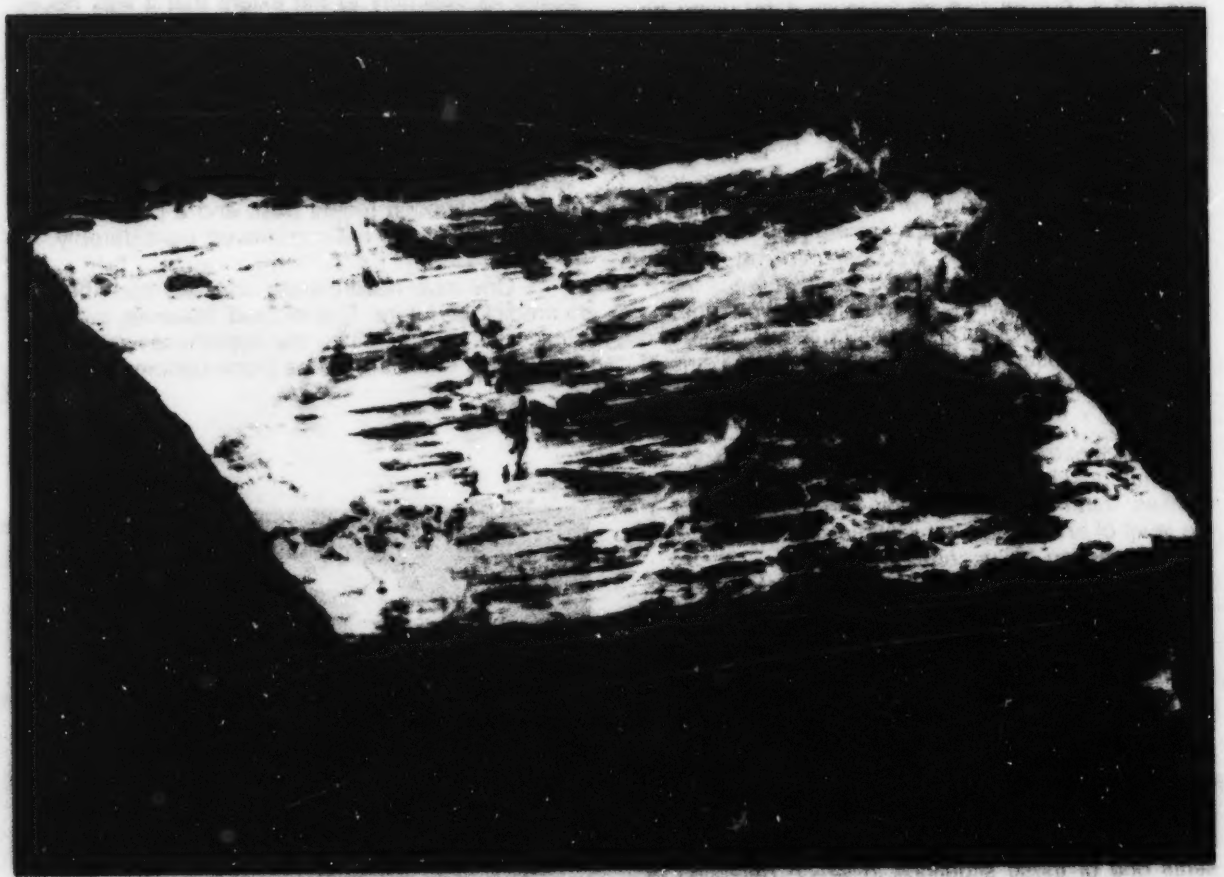
Technological improvement in dust control and handling rules out direct comparisons between an obsolete, although recent past, and a present where sanitary conditions have improved considerably.

One must nevertheless use data from the past to predict the future. This method, however, is always subject to caution, since the hypotheses retained in the various studies may be incompatible.

Specimen of chrysotile in its natural state.

The present report therefore wishes to shed light on the facts concerning asbestosis and mesothelioma, by first identifying these two pathological manifestations.

Next, the epidemiological studies are dealt with, first at the level of the data collected, then, at that of the validity of the inferences which can be drawn. The evolution and orientation of fundamental research ends the physiological aspect. Concepts of salubrity and safety in the industry are the object of the second part and lead up to the socio-political environment.



Specimen of chrysotile in its natural state.

The texture of chrysotile has earned it the surname of cotton stone.

1. ASBESTOS AND HEALTH

1.1 Review

1.1.1 Asbestos

The term "asbestos" is a practical word of no precise mineralogical significance, which defines fibrous silicate minerals which are fire resistant, and which are either amphibolous (amosite, crocidolite, etc.) or serpentine (chrysotile, etc.).

Chrysotile, or white asbestos, produced in Québec is found in the form of fibres, composed of micro-fibrils in the shape of rods, whose basic structure is a multiple crystalline arrangement of the $Mg_3Si_2O_5(OH)_4$ group. The amphiboles, of which the best known are amosite (brown asbestos) and crocidolite (blue asbestos), have a basic structure of Si_4O_{11} and a variable content of metals, such as sodium, iron and magnesium. These variations affect the crystalline structure and account for the differences in acid resistance and tensile strength. Different applications therefore exist for the various types. Thus chrysotile is better than amphiboles in abrasive products whereas crodidolite is more efficient in some fibrous-cements.

The fireproof properties of asbestos have been recognized for several hundred years, and this mineral has been used sporadically since the times of the Romans. Its industrial usage really began only around 1870. In Québec, the mining of a deposit started in 1878 (production of 50 tons of raw fibre). With the start of production units in Russia (1895) and in South Africa (1900), usage increased consistently up to the early 1930's, at which time it started to soar significantly until the early 1970's. For the purpose of comparison, we can see that world production in 1976 exceeded the cumulative production up to 1930 (which was $5{,}6 \times 10_6$ t compared to $5{,}0 \times 10_6$ t).

This increase in production was essentially due to a diversification in asbestos uses. At the beginning of the century, it was only used in textiles, brake linings and insulation products. But in 1959, Rosato [1] enumerated over 3 000 products containing one or several forms of asbestos. Since then, other uses have been marketed while hundreds of products were withdrawn from the market for reasons of obsolescence or more so, for reasons of health. We can, therefore, reasonably estimate that in 1980, about 3 000 asbestos products, for domestic use as well as for industrial use, were in circulation in the various industrialized countries.

Asbestos is also present in developing countries since its use in asbestos-cement pipes improves the quality of life and only involves importing relatively simple technology.

The number of workers exposed to asbestos in the course of their professional activities has, therefore, grown so extensively that health problems related to its handling have gone directly from an anecdotal state to that of a painful reality.

1.1.2 Health

The history of industrial illnesses related to asbestos starts with its initial industrial uses, especially in weaving mills. The working conditions which prevailed in the industry at the beginning of the century were unacceptable according to present criteria. In 1930, according to Merewether [2], one of the current operations causing the most dust consisted of spreading various types of fibres on the floor in successive layers, and then cutting them and feeding the machines manually by means of a chute. This operation produced so much dust that the operators did not see further than their arms' length.

This type of industry had been operating in the same routine manner for almost 50 years, despite a few scattered indications about the danger of asbestos. In fact, the relationship between pulmonary fibrosis and asbestos had been established in 1900 and reported in 1906. This relationship, established at the autopsy, did not have the impact it would have today, since on the one hand, other causes of fibrosis could not be eliminated and on the other hand, the mentality and habits of that period were different.

It was not until 1927 that the term "asbestosis" appeared, together with a description of this characteristic ailment [3,4]. The phenomenon, then, was still marginal considering the small number of cases recorded, but it was taken seriously enough that some recommendations of the Merewether report were implemented in the early '30s. Politico-

[1] The figures in brackets refer to the bibliography at the end of the text.

economical upheavals having obscured research done in the '30s and '40s, it was not until 1955 that Doll [5] established a clear relationship between asbestos and cancer.

In 1960, Wagner [6] linked pleural mesothelioma to asbestos. Then came the first epidemiological studies of the Selikoff group [7,8] and the turning point of the '60s, the New York Academy of Sciences conference [9], which projected the debate not only in the scientific community but more so into the political arena.

The following decade, while it saw asbestos production reach its peak, was ultimately no more than the preparatory phase of present developments. Many cases of asbestosis resulting from poor working conditions in the '30s and '40s, contributed to the building of the bad reputation now associated with this product.

1.2 Asbestos Related Diseases

1.2.1 Asbestosis or Fibrosis

1.2.1.1 Description

The definition of asbestosis, retained by the task force on occupational respiratory diseases of the Department of National Health and Welfare (Canada) in 1979, reads as follows:

> *"diffused pulmonary interstitial fibrosis caused by the inhalation of breathable asbestos respirable dust (fibres) with or without accompanying reaction of the visceral and or parietal pleura"*[1].

Normally this fibrosis is found in the lower part of the lung[2]. However, despite the relative rarity of pulmonary fibrosis, none of the symptoms related to this disease is exclusively associated with it. The identification of asbestosis among detected fibrosis cases thus requires a long and tedious process.

Fibrosis may be caused by factors other than asbestos: various inorganic dusts (silica among others), certain organic dusts as well as a host of internal factors. These factors, for instance, are the cause of pulmonary sarcoidosis, which sometimes resembles asbestosis in every respect. An asbestosis diagnosis cannot therefore be established until other possible causes have been eliminated, even if the patient has been subjected to sufficiently high asbestos exposure.

Although recognition of asbestosis as an industrial disease goes back half a century, the development of diagnostic criteria is still being pursued. We should not be surprised, therefore, that certain individuals identified a few years ago as having "asbestosis", today find themselves in a state of health which is not compatible with asbestosis diagnosis.

The different types of asbestos have varying fibrogenous capabilities, but the ailment generally follows the same course. Fibrogenous capabilities depend first of all on the shape and size of the fibre. The largest fibres are retained by large air passages while the fine dusts remain in suspension long enough to be exhaled: only "medium" size fibres deposit on the lung surfaces.

Fibres which are less than 5 microns in length are easily neutralized when they deposit on lung surfaces, and those which have a diameter greater than 5 microns cannot reach the alveolar cavities.

Because of their needle-like structure, amphiboles penetrate into the lungs much more easily than chrysotile fibres which, because of their shape, deposit more slowly. However, the tendency of the latter type of asbestos to break down more readily into finer structures, can facilitate its penetration.

1.2.1.2 Observed Relationships

The mortality rate is 2,8 times higher among asbestosis patients than in a reference group[3] of the general population [11]. Even if asbestosis is directly responsible for only 20 % of deaths among asbestosis victims [12], the spectre of cancer remains present since it represents one of the frequent causes of death in this group, particularly among smokers.

— relationship between the severity of the disease and the fibre content of the lungs.

The development of asbestosis is not influenced by the quantity of asbestos dust deposited in the lung except for the first serious phases: the progression of the disease from a moderate degree of severity to a higher level does not depend on the fibre content of the lung. Likewise, the severity of asbestosis and the duration of exposure[4] are not related[5] at

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1. *Definition drawn from Parkes [10].*
2. *Contrary to silicosis, where fibrosis is nodular and is located in the upper part of the lung.*
3. *A group of individuals who have the same characteristics except for one trait, in this case asbestosis.*
4. *Or the time lapse after the first exposure, or even the time lapse between the last exposure and death.*
5. *In the case of silicosis, the severity of the disease is related to the dose.*

all. These results suggest that light and moderate asbestosis are proportionally related to the quantity of fibres in the lung but that the development of severe fibrosis depends on other factors. An infection [13], nicotinism, and even immunological susceptibility [14] were suggested as possible causes.

— cancer

Stratification of the population according to the type of work reveals, at least in England, a greater incidence of lung cancer among factory workers. However, a high correlation between this occupation and nicotinism is also noted as well as living in multi-dwelling urban neighborhoods and a lower than average standard of living, all factors which were associated with a resurgence of lung cancer.

Moreover, tobacco is known as a cause of lung cancer. More than 100 residuals of cigarette combustion have known carcinogenic properties. It is no surprise, therefore, that this factor was taken into account in the majority of recent studies. Tables 1 and 2 show the multiplicative effects of asbestos and tobacco. All things being equal, smoking shows up as much more of a risk than asbestos. Table 3, developed from Higginson's data [15], brings to light the relative harmlessness of asbestos as a separate entity.

However, the multiplicative effect leads to the belief that asbestos contributes to the development of cancer as a co-carcinogenic (element or promotion). The promoter does not directly induce cancer but it creates conditions which promote its development. Asbestos does not increase cancer frequency, except through asbestosis which it induces[1]. There is a clear relationship between lung cancer and the degree of pulmonary fibrosis [20] as much in asbestosis as in other forms of fibrosis [21,22][2].

Table 1

Relative Risk[1] of Lung Cancer Among American Insulation Workers

Nicotinism \ Exposure to Asbestos	No Exposure	Exposure
Non-Smokers	1	5
Smokers	11	53

1. The basis of the risk is the rate of lung cancer among non-smokers.
Source: McDonald, J.C., 1982 [53].

Table 2

Relative Risk[1] of Lung Cancer Among Québec Chrysotile Workers

Nicotinism \ Exposure to Asbestos	Slight	Moderate	Heavy
Non-Smokers	1	2	7
Moderate Smokers	6	8	13
Heavy Smokers	12	13	25

1. The basis of the risk of lung cancer among non-smokers.
Source: McDonald, J.C., 1982 [53].

However, one must differentiate the different types of asbestos when analyzing their effects. Studies by Webster [23], McDonald [24] and Seidman [25], suggest that crocidolite and amosite are more carcinogenic than chrysotile. This could be explained by the fact that chrysotile is partly eliminated by dissolution, contrary to amphiboles which remain completely intact in the tissues [26,27].

Table 3

Bronchial Carcinoma in Various Populations

Type of Population	Incidence per million	Relative Risk
Non-Smokers (30% of the population)	8	1
General Population	60	7
Smokers (all of them)	85	10
Heavy Smokers	130	15
Non-Smoking Asbestos Workers	8	1
Asbestos Workers (Smokers)	560	70

Source: Preger, L., in Asbestos Related Disease, Grune and Stratton Inc., N.Y., 1978, p. 175.

1. This acknowledgment is based on experiments with animals (16) as well as on studies with man [17, 18, 19].
2. The sole exception is silicosis.

Unfortunately, comparisons between the effects of different types of asbestos on man suffer from the lack of reliable statistics describing the degree of exposure to fibres. The hypotheses which underlie each measuring method, vary from one study to another, which makes comparisons impossible. Some studies measure the dust level in millions of particles per cubic foot (mppcf), while others measure it as breathable fibres per cubic centimetre (f/cc). As the proportion of breathable fibres is very different from one variety to another, for a given dust level, the quantity of amphiboles retained would be greater than the quantity of chrysotile for example.

1.2.1.3 Apparent Decline in Asbestosis

Valid data on asbestosis are available in England and Canada, more particularly in the organizations responsible for applying compensation laws for industrial diseases. These institutions compile the number of cases diagnosed for compensation purposes.

In Great Britain, at the end of the '50s, approximately 30 new cases of asbestosis were recorded each year [28], whereas between 1973 and 1976, 133 cases were recorded annually [12]. Since the cases of asbestosis currently registered result from past exposure (i.e. in the '40s), this growth reflects the poor health conditions which prevailed at that time.

Table 4, which includes the most recent statistics of the Commission de la Santé et de la Sécurité du travail (CSST) on asbestosis, shows a reduction of this disease in Québec. This reduction should nevertheless be seen in the light of the numerical decline of the target group and the improvement of diagnostic criteria. The fact remains that the improvement in asbestosis tracing and in working conditions should progressively reduce the number of new cases of asbestosis and associated cancer, to the point of elimination.

The most common types of mesothelioma affect the pleural and abdominal cavities, giving rise to pleural mesothelioma and peritoneal mesothelioma respectively. In the first case, the tumor gradually covers the lung and causes pleural effusions. It sometimes reaches the pericardium or even the abdominal cavity. It spreads on the surface like a film but does not penetrate into the subjacent tissues.

Histogram of Asbestosis Cases Reported in Québec According to the Rate of Known Incapacity per Civil Years

(ordinate: number of cases)

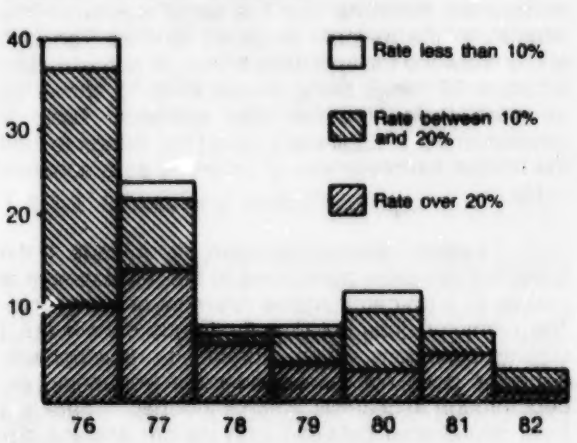

Table 4

Asbestosis Cases Registered in Québec, from 1976 to 1982: Distribution According to Known Rate of Permanent Incapacity

	1976	1977	1978	1979	1980	1981	1982
Number of cases submitted	421	173	80	80	120	109	98
Known rate							
0 %	381	149	72	72	108	102	95
5 – 9,9%	3	2	1	1	2	0	0
10 – 19,9%	27	8	1	3	7	2	2
20 %	10	14	6	4	3	5	1
Number of cases accepted	40	24	8	8	12	7	3
% accepted	9,50	13,87	10,00	10,00	10,00	6,42	3,06

Source: CSST statistics (on 1/3/83).

Asbestos-cement pipe.

Asbestos-cement building.

Caribbean house made of asbestos-cement.

Brake pads made from asbestos.

Aesthetics, durability, reliability: asbestos products lend themselves as much to the needs of industrialized countries which insist on safety and versatility as to those of developing countries which are seeking quality and an improved standard of living.

Moreover, recent studies in the asbestos industry among populations exposed to concentrations lower than 20 fibres per cubic centimetre, indicate that lung cancer and asbestosis would be in regression in the case of workers exposed to chrysotile [29,30]. Nevertheless, these groups should be monitored longer to obtain data taking into account the latency phenomenon.

1.2.2 Mesothelioma

1.2.2.1 Description

Mesothelioma is a malignant tumor of the mesothelial tissue which covers certain cavities of the body such as the pleural and abdominal cavities. Described by Harris [31] in 1894, that is before the expansion of the asbestos market, it regained prominence on the scientific scene in 1960, when a higher incidence was noticed among crocidolite mine workers in South Africa [6]. Since then, in people's minds, it has become **the asbestos cancer**.

To establish a precise mesothelioma diagnosis, it is necessary to know if the tumor is the inital host and not a secondary centre of cancer. Usually, only an autopsy can ascertain this fact, although the use of special techniques makes it possible for an aware pathologist to make a fairly accurate diagnosis.

Difficulties encountered in establishing diagnosis and serious doubts weighing on the very existence of this type of tumor can explain the small number of cases reported between 1900 and 1950. This could have led to the erroneous belief that the illness was rare. Besides, one must admit that with a life expectancy of approximately two years, the observation periods are short. The existence of many forms of mesothelioma as well as their resemblance to some other tumors have been the cause of several mistakes [32]. It was therefore difficult, until recently, to evaluate the real incidence of this tumor. Besides, it has only been classified as a diagnostic entity since 1979, at the ninth revision of the International Code of Diagnosis (I.C.D.).

Peritoneal mesothelioma seems to propagate in a different way. It appears in the form of nodules which bind together so as to form compact masses that invade free spaces and progressively compress the viscera. The rapid development of this type of tumor prevents secondary centres from appearing; this absence of secondary centres was part of the diagnosis a few years ago.

Table 5

Relative Frequency of Pleural and Peritoneal Mesotheliomas in Populations not Exposed to Asbestos

References	Populations	Mésothéliomas		%
		pleural	peritoneal	peritoneal*
Connelly (1980)	SEER (1973-78), males	369	43	9
Breslow (1982a)	TNCS (1969-71), males	83	9	10
Breslow (1982a)	Patients in cancer monitoring and treatment centres, United States (1978-1980)	234	36	13
Elmes and Simpson (1976)	No known exposure	52	7	11
Baris et al (1979)	Turkish villagers in a hyperendemic region	20	1	5
McDonald and McDonald (1980)	Canadians & Americans without any known exposure (1962-75)	119	37	24
Brenner et al (1981)	Children	40	7	15

SEER: Programme Survey, Epidemiology and End Results.
TNCS: Third National Cancer Survey.

** The percentage is calculated taking into account mixed mesotheliomas which are not included in the table.*

1.2.2.2 Relationships Observed

Table 5 summarizes the findings of the principal studies on mesothelioma carried out with populations not exposed to asbestos. Pleural mesothelioma is about 6 times more frequent than peritoneal tumor. The average age of those affected is between 55 and 65 years for the pleural type and between 45 and 55 years for the peritoneal type.

Several cases of mesothelioma have also been reported among those under 20 years of age [33]. Their distribution according to sex and the peritoneal/pleural ratio are analogous to these found in adults not exposed to asbestos [34,35]. In view of the latency period which precedes the appearance of the disease, this cannot be explained by the exposure of the child to asbestos. The possibility of a genetic influence was mentioned [36].

These mesotheliomas where exposure to asbestos is excluded represent over 33% of the mesotheliomas diagnosed. In fact, the percentage varies from 0 to 80% according to published data.

Table 6

Relative Frequency of Pleural and Peritoneal Mesotheliomas Among Moderately Exposed Populations

References	Populations	Mesotheliomas		% peritoneal*
		pleural	peritoneal	
Elmes and Simpson (1976)	Minor exposure	151	10	13
Chovil et al (1981)	"Compensated" mesotheliomas, Ontario	23	9	28
McDonald and McDonald (1980)	Trades related to construction, United States and Canada	117	19	16

** The percentage is calculated taking into account mixed mesotheliomas which are not included in the table.*

Table 7

Relative Frequency of Pleural and Peritoneal Mesotheliomas Among Heavily Exposed Populations

References	Populations	Mesotheliomas		% peritoneal*
		pleural	peritoneal	
Selikoff (1980)	American insulation workers	63	112	64
Newhouse (1981)	English workers	10	16	62
Newhouse (1981)	English textile workers (female)	12	8	40
Finkelstein (1981)	"Compensated" Canadian workers	5	4	44
McDonald and McDonald (1980)	Canadian & American insulators, miners and factory workers (1960-1972)	29	23	44
Hobbs et al. (1980)	Miners and employees of crocidolite plants	25	0	0
Elmes and Simpson (1976)	Mesothelioma cases, United Kingdom (1960-1969)	64	20	29

** The percentage is calculated taking into account mixed mesotheliomas which are not included in the table.*

The mesothelioma-asbestos association is therefore not exclusive.

Light or average exposure to asbestos does not affect the pleural/peritoneal ratio (see table 6). But high exposure changes this ratio substantially. Table 7 reports the results of studies involving heavily exposed workers. Except in the case of crocidolite miners [37], the predominance of the pleural type is eliminated if not reversed[1]. Certain peritoneal mesotheliomas may therefore be associated with heavy exposure to amphiboles.

It seems that the different types of asbestos act on different areas, with varying impact. The use of amphiboles presents a greater risk of mesothelioma than that of chrysotile. Peritoneal mesothelioma is initiated, most of the time, by amosite[2]. It is not found among crocidolite workers [37] nor among workers who handle only chrysotile. But combined exposure to chrysotile and crocidolite increases the proportion of peritoneal mesothelioma.

The ratio peritoneal/pleural mesothelioma appears to be an interesting variable which has not been studied in depth. It is true, however, that the number of studies in which the relationship mesothelioma/asbestos type, mesothelioma/exposure degree (in terms of duration and intensity) is quite limited.

1.2.2.3 Incidence

In the mid '70 s. the rate of mesothelioma in the population in general was about 8 per million among men and 2,5 per million among women [41]. This rate is rising among men and it is relatively stable among women. However, the implicit rate for males 50 years old and over is of the order of 4 cases per 100 000 per year. Pleural mesothelioma seems more frequent than peritoneal mesothelioma when asbestos exposure is non existent.

This low incidence has led some authors to conclude that asbestos alone is responsible in cases of mesothelioma occurring in the families of workers exposed to asbestos. A great deal has been made of the cases where the daughter or the son died of mesothelioma like the father/mother.

1.2.3 Other Forms of Cancer

Several studies show an increase in the incidence of certain types of cancer, particularly gastrointestinal ones. Very sporadically, reports indicate an increased incidence of cancer of the kidneys, breasts and ovaries.

However, a direct relationship between asbestos and these cancers has yet to be proven. The choice of a valid reference population is difficult. The other known risk factors, such as eating habits, heredity, alcohol and tobacco use, were not considered in the early studies. Thus more articulate complementary studies have invalidated the first conclusions.

1.3 Epidemiological Data

Epidemiology studies existing relationships between sicknesses and various factors (life style, ambient or social environment, individual particularities) capable of influencing these diseases, their frequency, their distribution, their evolution. The key factor here is asbestos exposure.

The method followed in epidemiological studies consists in monitoring the largest possible number of workers in an asbestos related industry and analyzing the causes of death. For each cause, the recorded number of deaths is compared to the number expected in a reference population. The ratio of the first over the second is the standard mortality ratio (SMR).

For practical considerations, adjustments are necessary. Simplified hypotheses must be set down to compare given populations. To isolate one factor while keeping all other elements constant is not feasible in reality. Therefore, all studies are biased. One thus tries to minimize biases inasmuch as the time and financial means allocated to the study as well as the quality of data permit.

1.3.1 Major Studies

The most significant group of workers monitored was that of the American insulation workers. Since 1964, it has been the subject of a series of publications of the Mount Sinai School of Medicine in New York. Next come the Québec miners and mill workers who were examined by the McGill University group. In England, the Newhouse team studied several populations such as the textile workers and the abrasive products plants workers. These studies cover more than half the asbestos workers surveyed and analyzed.

Table 8, drawn from McDonald [41], gives the results of the major studies on cancers of the respiratory passages and of the digestive system published before 1981. The results vary a lot from one

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1. In studies by Selikoff [38] and McDonald [35], the number of common subjects is indeterminate. The study of Elmes [39] underscores the number of peritoneal mesotheliomas.

2. On this subject, at the World's Symposium on Asbestos held in Montreal, Julian Peto declared: "...I have separated peritoneal cases, which seem to be caused most frequently by amosite, less often by crocidolite, and very rarely by chrysotile alone..." [40].

Can today be compared to yesterday? Bagging which used to be an entirely manual operation now to is completely automatic. Efficiency and safety go together.

Table 8
Summary of Major Epidemiological Studies on Asbestos

	Reference	PD[b]	Cohort	Deaths	Mesotheliomas	CANCERS: Respiratory Code ICD 162-3[a] O[c]	CANCERS: Respiratory Code ICD 162-3[a] A[d]	CANCERS: Digestive Code ICD 150-9[a] O[c]	CANCERS: Digestive Code ICD 150-9[a] A[d]
			MALES						
Mining and milling									
Chrysotile	McDonald et al. (1980)	100	9,850	3,291	10	230	184,0	276	272,4
	Nicholson et al. (1979)	35,6	944	178	1	28	11,0	10	9,5
	Rubino et al. (1979)	69,5	933	332	0	10	10,4	19	19,3
Anthophyllite	Meurman et al. (1974)	31,8	1,041	248	0	21	12,6	7	8
Talc	Kleinfeld et al. (1967b)	7,8	220	91	2	9	2,3	6	1,5
	Brown et al. (1979)	16,9	382	74	1	8	2,8	3	3,0
Crocidolite	Hobbs et al. (1980)	ns[e]	4,960	181	16	38	22,6	ns	ns
Manufacture									
Chrysotile	Elwood et Cochrane (1964)	ns	1,024	46	1	6	3,0	ns	ns
	Weiss (1977)	8,4	264	66	0	8	8,6	2	2,0
	Dement et al. (1981)	27,4	746	191	1	26	7,5	9	7,1
Crocidolite	McDonald et McDonald (1978)	8,4	93	43	8	8	4,0	1	2,0
Amosite	Seidman et al. (1979)	66,0	820	528	14	83	22,8	ns	ns
Mixed	Hawhouse et Berry (1979)	81,8	2,887	545	46	103	43,2	40	34,0
	Hawhouse et al. (1981)	99,9	8,804	1,640	8	143	139,5	103	107,2
	Peto et al. (1977)	57,3	796	293	9	49	22,9	ns	ns
	Henderson et Enterline (1979)	86,1	1,075	781	4	63	23,3	551	39,9
	Robinson et al. (1979)	89,1	2,666	912	13	49	36,1	501	41,4
	Hugues et Weill (1980)	93,1	5,645	601	0	49	49,1	25	50,1
	Mancuso et Coulter (1963)	25,8	1,266	175	4	15	5,5	121	7,0
Insulation									
Mixed	Kleinfeld et al. (1967a)	11,6	152	46	4	10	1,4	7	2,7
	Selikoff et al. (1979)	48,6	632	478	38	93	13,3	ns	ns
	Selikoff et al. (1979)	99,3	17,800	2,271	175	129	108,6	122	84,1
	Elmes et Simpson (1977)	11,7	162	122	13	35	5,0	ns	ns
	Hawhouse et Berry (1979)	20,3	1,368	83	10	21	5,6	3	4,3
Shipyards									
Mixed	Rossiter et al. (1980)	99,3	6,076	1,042	28	88	100,7	73	83,3
	Kolonel et al. (1980)	ns	4,779	385	3	351	23,5	ns	ns
			FEMALES						
Manufacture									
Crocidolite	Jones et al. (1980)	67,8	578	166	17	12	3,8	10	20,3
	McDonald et McDonald (1978)		83	13	2	0	0	1	0
Mixed	Peto et al. (1977)		284	24	1	2	0,9	ns	ns
	Hawhouse et Berry (1979)	36,5	783	200	21	27	3,2	3	4,3
	Hawhouse et al. (1981)	76	4,219	346	2	6	11,3	29	27,4
	Robinson et al. (1979)	29,4	544	128	4	14	1,7	8	6,8
	Mancuso et Coulter (1963)	6,6	229	20	1	4	0,2	2	1,0

a) Classification of the tumors considered.
b) Power of detection measured as the percentage of chance to measure a 1,5 SMR effectively.
c) Number of deaths observed in the cohort.
d) Number of deaths expected according to the reference population.
e) ns = not stated.

Source: McDonald, J.C. 1981[41].

study to another. In certains cases the number of deaths recorded among a group of workers under observation exceeds that expected in the reference population in a proportion of up to 2 000% for cancers of the respiratory passages and 400% for cancers of the digestive system. Sometimes, on the contrary, it is the reference population which presents a surplus of deaths. This absence of consistency indicates that the same phenomenon is not measured under the same conditions.

The different types of asbestos and the different processes can explain some of the variations observed. Each type of fibre has a particular pathogenic effect. Manufacturing operations would present more serious risks. When handled, many fibres break down and divide into smaller fibres which penetrate into the lungs more easily. Furthermore, cancer inducing substances are adsorbed during operations which follow extraction. The intensity and duration of exposure to asbestos, selection of cohorts[1], validation of the causes of death, life styles, personal predispositions and methodological errors also affect the standard mortality ratios.

In the following part of this section only studies covering chrysotile, the sole type of asbestos exploited in Québec, will be considered, those which only cover amphiboles will be left aside.

1.3.1.1 Epidemiological Studies Carried out in Mines and Mills

McDonald made the most important study in this category. His team monitored almost 10 000 individuals in a minimum of 15 years. Table 9 is drawn from this study. Examination of deaths due to tuberculosis[2], lung cancers, cancers of the oesophagus and the stomach, shows a relation between the exposure rate and these illnesses. A minor or moderate exposure to asbestos produces and SMR of 1,15 for lung cancer and 1,05 for oesophagus and stomach cancers[3]. Because of the small number of cases, a difference of one or two deaths could inflate the report and indicate a relationship that does not really exist.

Heavy exposure, according to McDonald, causes and SMR of 2,65 for lung cancer. Nicholson reports a value of 4,25.

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1. Group of individuals forming part of the analysis.

2. Today it is a known fact that there is no relation between chrysotile and tuberculosis. Thus the absolute value of SMR has only a relative importance.

3. In a population showing factors common to those observed by McDonald, Nicholson [42] finds an SMR of 1,55 for lung cancer. The dose is greater: 50 fibres per cubic centimetre in his study, compared to 20 in McDonald's study. The duration of exposure is not specified by Nicholson whereas McDonald monitors workers with over 20 years of service.

Table 9

Mortality Table of Asbestos Miners Having Worked Over 20 Years in Québec Mines and Mills

Accumulated Dose	Light		Moderate		Heavy		Very Heavy	
Mortality Causes	D.R.*	SMR	D.R.*	SMR	D.R.*	SMR	D.R.*	SMR
All causes	367	0,98	253	0,89	183	1,07	295	1,50
Pneumoconiosis	4	10,49	7	23,75	5	30,10	20	101,52
Malignant Tumors								
Lung	28	1,21	20	1,08	24	2,20	32	2,65
Oesophagus & Stomach	17	1,36	6	0,64	8	1,44	19	2,89
Colon, Rectum	7	0,56	4	0,43	1	0,18	9	1,39
Other Parts of the Digestive Tract	10	1,18	3	0,46	2	0,51	6	1,35
Larynx	2	1,07	1	0,69	0	0	1	1,03
Others	33	1,23	16	0,79	11	0,90	19	1,36
Cardiovascular Diseases	138	0,87	115	0,95	77	1,06	94	1,12
Tuberculosis	5	1,01	5	1,31	3	1,27	9	3,06
Other Respiratory Diseases	18	0,92	10	0,68	14	1,62	17	1,74
Cerebrovascular	32	1,15	18	0,89	10	0,84	22	1,58
Accidents	16	0,82	19	1,16	9	0,85	12	1,01

** Number of deaths recorded.*
Source: McDonald, J.C., 1980 [24].

Although these last results vary greatly in absolute value from one study to another, they reveal a significant excess of diseases attributable to asbestos. Other factors may have exercised an influence but they did not create the problem. This observation applies among others to cigarettes: the proportion of non smokers and light smokers among asbestos miners victims of cancer, is higher than among the reference population.

No significant excess of mesotheliomas was observed. This illness only accounted for 0,2% of deaths.

1.3.1.2 Epidemiological Studies in Factories

Conclusions based on these studies can be summarized as follows: the asbestos-cement industry[1] presents less risk than that of abrasives[2], which presents less risk than the textile industry[3]. The risk seems proportional to the age of the industry.

Studies in factories encountered greater obstacles than those carried out in mines and processing plants. It is difficult to obtain reliable data on chrysotile exposure in factories. Workers exposed exclusively to this type of asbestos are difficult to trace because of the mobility of labour and the void in company files as well as because of their modest size. Moreover, dust measurements (when they are given) only have a relative value since they are often based on estimates.

Thus methodology problems are greater in these studies, but the results are constantly being refined as research on these groups of workers progresses. Such is the case of a study made by Elwood in 1964 [50], which sets an SMR of 2 for lung cancer in an asbestos-cement plant Thomas went over this study in 1982 [43] and came to different conclusions. He demonstrated that there is no excess of this type of cancer and that the SMR is only 0,93.

1.3.2 Validity of Conclusions

Our knowledge of biology is still incomplete, however, it develops and becomes more and more refined. The limitations of the conclusions derived from this knowledge will be qualified as "biological".

An epidemiological study gives a representation, a model of reality which is bound to be a simplification. Besides, the epidemiologist deals with an established fact, which he cannot control. These two elements introduce limitations which will be qualified as "methodological".

Such limitations must be recognized and taken into consideration, particularly when projections are made based on relationships observed in epidemiological studies.

1.3.2.1 Biological Limitations

There are no historical statistics describing past dust density in terms of breathable fibres. Epidemiological studies do not mention any exact value concerning dosage. The charge accumulated in the past was then estimated on the basis of current dust conditions. It is the product of the concentration of fibres in the air by the number of years of service.

However, this measure gives rise to reservations. Exposure to a concentration of 100 fibres per cubic centimetre for one year and exposure to 2 fibres per cubic centimetre for 50 years both give a cumulative dosage of 100 fibres per year. However, the effective dose retained by the lungs is not the same in both cases. These can easily rid themselves of a weak dose they are subjected to over a 50 year period. Under certain physiological conditions chrysotile can dissolve [51]. Thus the dosage retained is quite different from the cumulative dosage. Analogically, to be hit by an automobile going at 50 km/hr may cause death, whereas to be hit 100 times at 0,5 km/hr by this same vehicle should not endanger one's life.

The conclusions reached by means of this particular measure are therefore restricted. The cumulative dosage is only an exposure index, that is an instrument for comparison whose absolute value has no significance in itself. It is useful to compare a cohort exposed to asbestos with a reference population, when both groups have the same characteristics. If need be, it can be used to compare different groups which have been subjected to similar exposures, if the conditions of exposure are about the same.

The exposure index is part of the simplified representation of reality intended to facilitate the processing of available data. It should not be considered as a biological reality.

---

1. In the asbestos-cement plants, Thomas [43], Lacquet [44] and Weill [45] report SMRs of 0,93, 0,98 and 1,04 respectively.

2. In the abrasive products plants, Newhouse arrived at an SMR of 1,08 [46], 1,18 [29] and McDonald [47] at an SMR of 1,58.

3. In the textile plants, Newhouse [48], Dement [49] and McDonald [47] find SMRs of 4,62, 3,47 and 2,67 respectively.

1.3.2.2 Methodological Limitations

The epidemiologists' method has two sources of limitations: the experimental approach and the social nature of the phenomenon studied. The experimental approach consists in drawing from reality a model, that is a simplified representation. But the simplifying inevitably leads to a bias. The model must thus be tested in order to minimize the discrepancy (bias) which separates it from the reality it describes. When certain elements of the model are estimated mathematically, one must establish the validity of the statistical values obtained.

The epidemiologist faces another problem: he measures the results of a social fact. He has not created it and he does not control its course. He does not have access to all data since his sources are often incomplete.

Two causes of the bias affecting epidemiological studies have been identified. The first one is related to the heterogeneousness of the population exposed. Two factors of heterogeneity have been isolated [64]: a chronological factor and a factor of selection. The first can be corrected by dividing the cohort into sub-cohorts of workers whose exposure to asbestos began at the same time. The length and degree of exposure may then be controlled. To eliminate the selection bias, a census must be made of the whole population to which the cohort belongs. But, since the sources of census — union and company files — are often incomplete, it is difficult to eliminate the selection bias.

The second source of bias comes from the reference population [52], which must be identical to the exposed cohort in every respect, except for exposure to asbestos. This can seldom be verified. Most epidemiological studies make corrections as to the age, sex, race, time of year, but they overlook nicotinism and the type of work.

Because of these biases, results of diverse studies do not often agree. Extrapolations drawn from these studies are too speculative. Attempts to correct or harmonize them often only bring on new biases. Improvement of the models requires a revision of their basis.

1.3.2.3 Risk Evaluation

Evaluation of the health hazard which low occupational exposure to asbestos[1] poses, clearly illustrates the phenomenon of limitations. As data which describe the degree of exposure are incomplete, models are used.

— Limitation surrounding the use of models

Existing models represent situations where prevailing exposure levels are high, that is in the order of 30 fibres/cc[2]. It is estimated that a man breathes 11,5 million cubic centimetres[3] of air every eight hours. Consequently, a worker subjected to 30 fibres/cc inhales about 350 million fibres per work day.

At a concentration of 1 fibre/cc, the quantity inhaled is in the order of 11 million fibres. This represents two totally different orders of magnitude. The extrapolations which can be drawn from the models to describe the risk presented by a mild exposure therefore allow a high margin of error. This constitutes a limitation to the use of these models.

— Proof of the significance of the limitation

Existing models were built on the assumption that all airborne fibres are dangerous to the health. Any extrapolation leads to the conclusion that mild exposure to asbestos poses a risk.

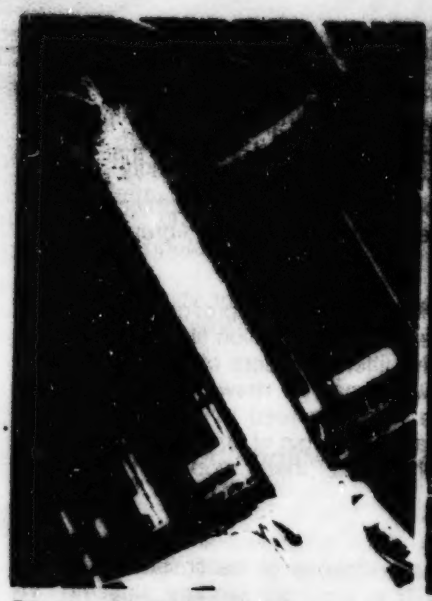
In view of the extent of the error margin associated with the use of these models, attention was directed to a situation which could present a risk analogous to light exposure in the workplace, that of Thetford Mines and Black Lake populations. In the '40s and '50s, asbestos dust covered the streets and balconies of these cities. Ambient air samples, taken during the '70s showed concentrations reaching an average of 0,07 fibre/cc[4]. The citizens therefore inhaled about 2,5 million fibres per day, that is a quarter of the occupational exposure of 1 fibre/cc.

Examination of about 4500 deceased over a period of 10 years [54] did not permit to trace, excessive mortality attributable to asbestos among the female population[5]. Therefore, the daily inhalation of close to 2,5 million fibres does not present a measurable risk.

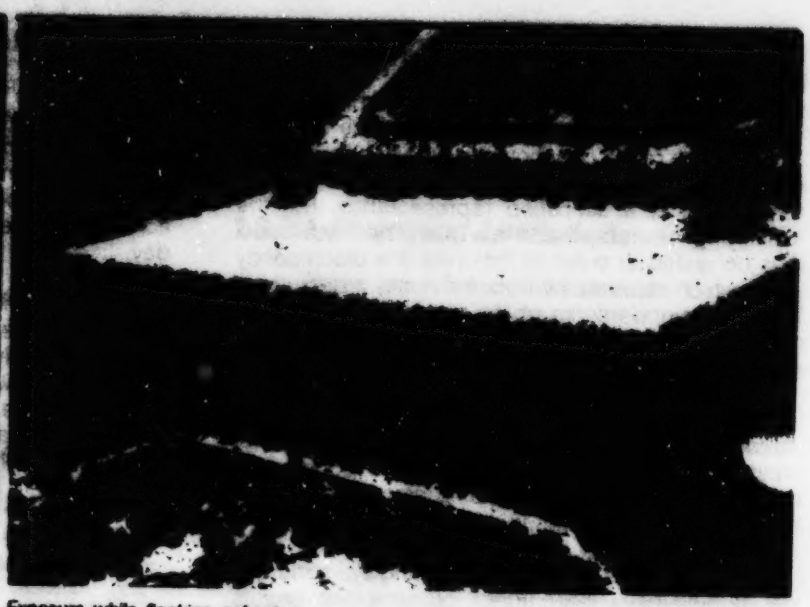
This result contradicts extrapolations already made from existing models. It also suggests the existence of a practical threshold, that is a concentration of fibres in the air within which health is not affected.

---

1. This corresponds to a concentration of 1 to 5 fibres/cc.
2. Observed concentrations extend from 10 to 100 fibres/cc.
3. 11,5 litres.
4. Some concentrations rose to nearly 1 fibre/cc.
5. The population exposed exclusively to dust in the town.



Exposure while flocking asbestos.



Exposure while flocking asbestos.

Textile mill.

Ignorance and laxism have led to bewildering working conditions. The adoption of a code of practice should eliminate dangerous situations while still allowing us to draw profit from the intrinsic qualities of asbestos.

1.4 Basic Research

Basic research comprises two facets: experiments carried out "in vivo", meaning in a living organism, and those performed "in vitro", which means in the laboratory, on isolated organs or on cell cultures. The "in vitro" techniques permit the observation of biochemical mechanisms which involve the introduction of an external element, that is asbestos, on a particular organ. These tests can nevertheless give an incomplete representation of reality. The organ that is actually affected may not be the one with which we are experimenting. The factor which causes the disease (in this case, asbestos fibre) can be transformed in the body before reaching the target-organ, which explains the usefulness of "in vivo" techniques: these take the entire body and the sequence of events which really existed into consideration.

The danger caused by the implantation and inhalation of asbestos fibres prohibits the use of human beings in these studies. Various species of animals were therefore used, each of which had particular characteristics similar to those of man, so as to present a faithful image of human reactions to asbestos.

1.4.1 Animal Implantation Model

Experiments consist in injecting groups of fibres in the peritoneum or under the skin. This permits to identify at a low cost the substances likely to initiate cancer in man. In early studies, asbestos fibres were implanted in massive doses. Tests were thereafter standardized in order to remedy for the incoherence of the first results.

Experiments on rats, mice and hamsters determined at what size the fibres are toxic. Stanton [26,55] injected these animals with groups of fibres of various length. Whenever their length exceeded 10 microns, the fibres were more toxic. Since their neutralization was incomplete, they tended to remain in the organism. However, the amplitude of the reaction depends on the physico-chemical properties of the fibres [56, 57][1].

The implantation model helped to study the development of fibrosis and cancer. However, none of the experiments have shown, to this day, that chrysotile altered the genes [58]. This is no doubt derived from the fact that these fibres are practically insoluble and that, consequently, they cannot reach the genetic material.

The implantation of different types of asbestos in the lungs of animals has made it possible to differentiate the effects of amphiboles and chrysotile. Crocidolite was found to be more carcinogenic than chrysotile, which confirmed the epidemiological studies. In rats, crocidolite induces more peritoneal mesotheliomas than chrysotile [59].

1.4.2 Animal Inhalation Model

A vast series of procedures and numerous animal species were used in tests aimed at copying human experience. It was necessary to get as close as possible to the reality that asbestos dust in the air constitutes for man. Chickens [60], rats and hamsters [61] were used according to a protocol established in the study of the carcinogenic effect of tobacco. However, the size of these animals limits the scope of the experiments since it does not permit a systematic evaluation.

Nevertheless, these experiments did permit to relate the aerodynamic characteristics of fibres to the different types of air flows which the dusts were subjected to in the respiratory passages. The retention of fibres in pulmonary tissues [16], their dispersion in the digestive system and their movement from the alveoli toward the lymphatic system were also measured.

The importance of anatomical differences between rodents and man[2] incited researchers to direct their attention to other animals — dogs and sheep [62]. The fibres were instilled in the trachea or inhaled by controlled breathing[3]. The equivalent or chronic exposure to asbestos was thus reproduced.

A series of practical indices describing asbestosis and lung cancers were then identified and monitored. They made it possible to observe the evolution of the diseases and to identify their phases of development. Thanks to these surveys, it should become possible to obtain a quick response "in vivo" which would allow early diagnosis of asbestos related ailments. Therefore, it should be possible, in the near future, to quickly detect people who are most sensitive to asbestos[4].

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1. Some physico-chemical properties of the fibres are described in appendix.

2. For example, a rat's nasal passages filter air much better than a man's.

3. With the aid of a plethysmograph.

4. In effect, the risk for these people remains, even if current extraction conditions hardly present any danger to health.

Laboratory: asbestos is handled in a closed area

Experimental inhalation model

Enormous sums were assigned to research aimed at getting a better knowledge and understanding of asbestos. No other substance of industrial usage has been the object of so much research.

1.4.3 Other Fibres

Stanton's study has inspired a considerable amount of research works on fibres, both natural and synthetic, used to replace asbestos. Even if epidemiological data do not identify any particular problem connected to their utilization (it is too recent), experiments on animals have shown that most of these fibres are as biologically active[1] as chrysotile fibres.

Among natural fibres, wollastonite has a toxic effect on men [63] as well as on animals [65]. The same applies to attapulgite, glass and rock wool [66]. Ceramic fibres have properties similar to those of chrysotile [67], its fibrogenic potential included. Some natural fibres are even known to be much more dangerous than asbestos. Such is the case with erionite, the natural fibre which is considered as being the most likely to contribute to the development of pleural mesothelioma [59].

This group of fibres is chemically different from asbestos but the similarity of their effects could be explained by a common characteristic: the adsorption of airborne carcinogens.

Recent studies tend to get away from Stanton's simplistic hypothesis and try to distinguish the "fibre effect" from other effects. An enormous effort of standardization toward that end has been realized in recent years.

The variations Bignon [68] noted in the results obtained in different laboratories [68] have led to a concertation for the establishment of procedures which revealed that the vast majority of substitute fibres present serious problems.

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1. This means that they disturb the activity of the cells. They may be either fibrogenous, carcinogenic...

2. SALUBRITY AND SAFETY

2.1 Salubrity

Salubrity is defined as a situation which poses no excessive health hazard. Its practical verification evolves under the influence of "tangible" (scientific knowledge) and "intangible" (public perception) factors. The "tangible" parameter which has commanded most attention is the quantity of asbestos dust in the air.

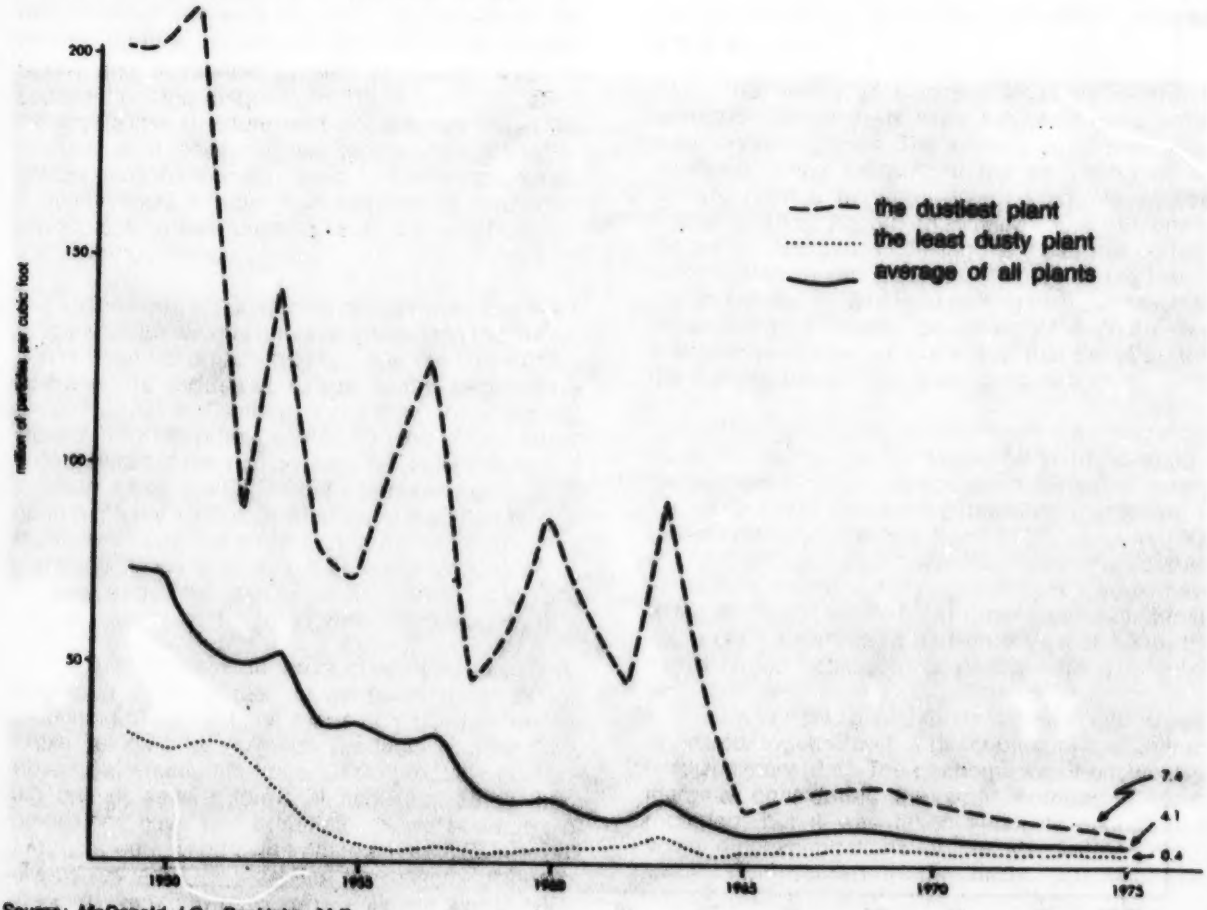
2.1.1 Evolution in Québec Mines and Mills

Salubrity in Québec mines and mills was studied by the Beaudry Commission in 1975 and 1976. Interested readers can consult this Commission's report [69].

Although awareness of asbestosis as an industrial disease began in Québec in the early '40s,

Figure 1

Dust Concentration in Québec Mills



Source: McDonald J.C., Becklake, M.R., « Asbestos-related diseases in Canada », in Hefte zur Unfallheilkunde, Heft 128; 2 Deutsch-Österreichisch-Schweizerische Unfalltagung in Berlin, 1975, Springer-Verlag, Berlin, 1976, 602

technical improvements were not introduced until the '60s (see figure 1). According to the testimony of certain miners, before the '50s, laborers in the plants were covered with dust while working. Cleaning of floors was infrequent. Salubrity varied considerably from one plant to another. That of the worst plant in Québec, in 1975, corresponded to that of the industry in general ten years earlier and to that of the best maintained plant twenty years before.

Since then dust levels in asbestos mills have been considerably reduced thanks to technological progress and the concerted efforts of all parties concerned. Asbestos mills are now among the cleanest and healthiest establishments one could visit. In this respect they uphold the comparison with all other mining establishments and with several other industrial installations.

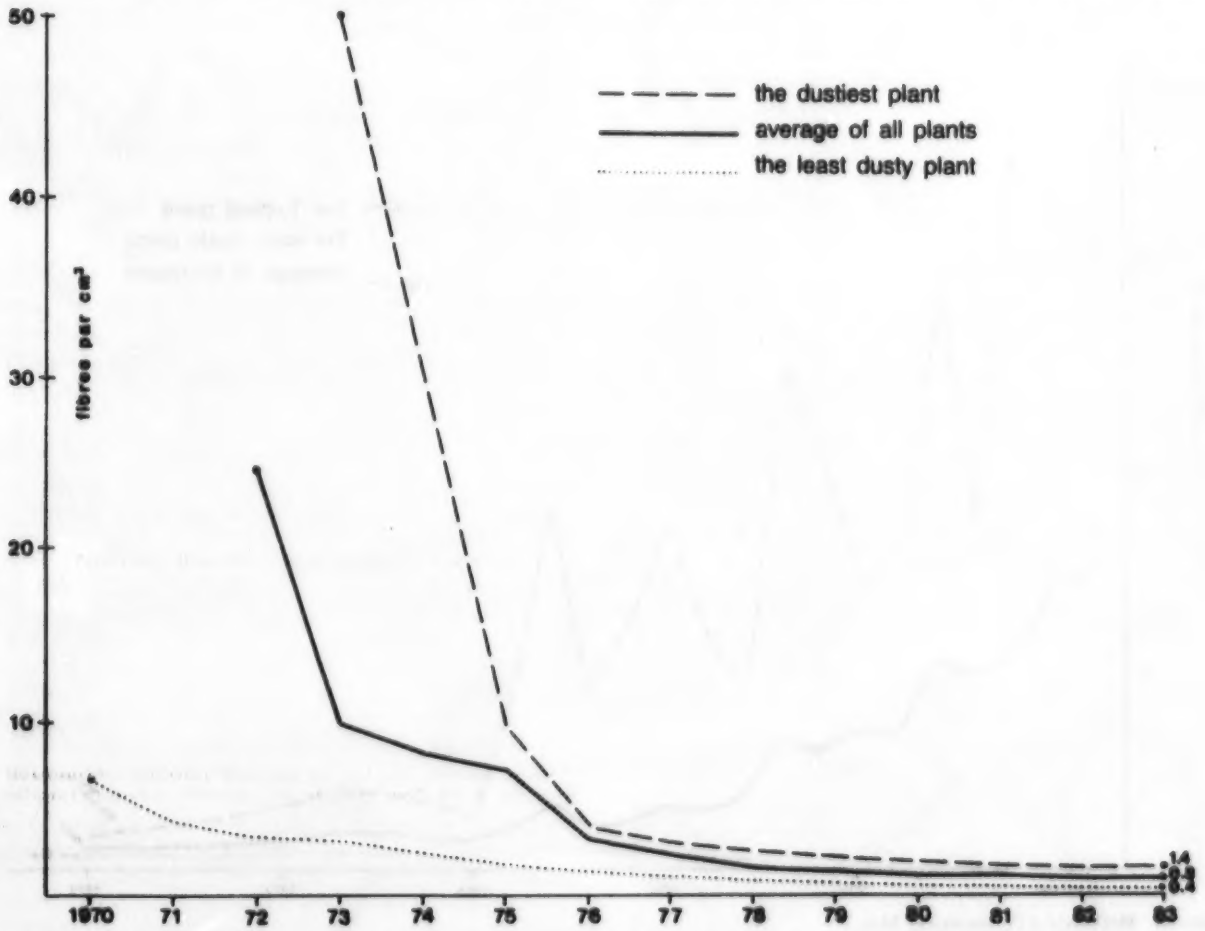
2.1.2 Evolution in the Processing Industries

The first indications of the danger inherent to asbestos handling came from the processing industry. This is why measures aimed at reducing exposure were introduced in certain textile mills in the '30s. These changes, although insufficient to satisfy current health criteria, did nevertheless improve working conditions.

England was the first country to recognize the problem of salubrity in asbestos processing. The

Figure 2

Dust Concentration (in fibres per cm³) in the Québec Asbestos Extraction Industry



* *fibres whose length exceeds 5 microns*

Sources: **Annuals of the New York Academy of Sciences,** *Vol. 330, 1979 and AMAQ's sampling reports.*

British industry was therefore forced to control dust concentration and to develop new manufacturing processes. The knowledge thus acquired was, however, very slowly disseminated to other industrial users of asbestos. As a matter of fact, health considerations in spinning mills were centered around carding and drawing; little attention was paid to the opening of fiber sacks and to grinding of the fibres, for example. Systematic examination of health conditions were only developed in the mid '60s, and this delayed the implementation of effective measures in other types of industry.

Manufacturing industries in other countries followed suit a few years later. So the awareness of health problems due to asbestos occurred in the same period in all countries, that is at the beginning of the '60s.

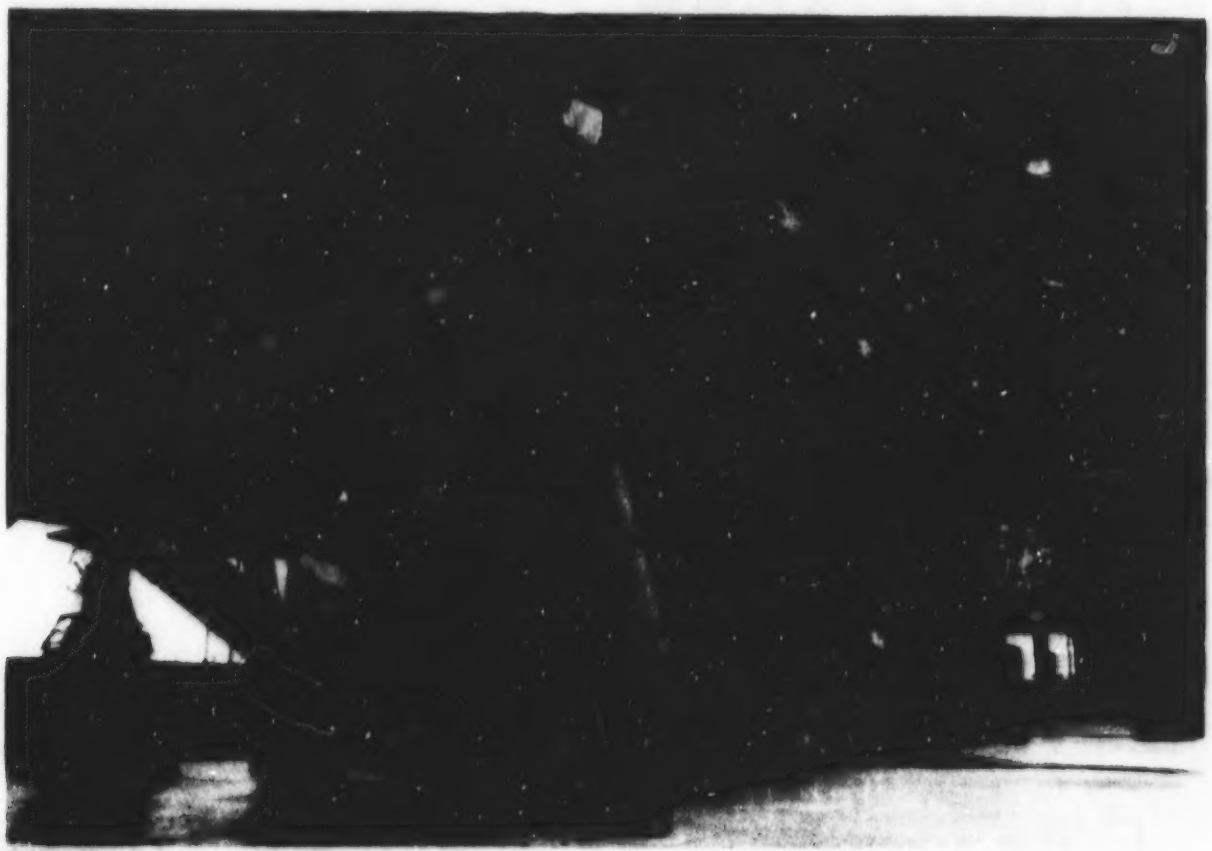
Despite the adoption of a global approach and the efforts undertaken about ten years ago, results do not correspond to the standards established in some industries. Market erosion and general competition from substitute products are partly responsible for the relative ineffectiveness of the health measures, which, in certain cases, bring with them financial weakening and technical disinterest.

2.2 Safety and Standards

Security can be defined as the sum of political, economic and individual actions aimed at achieving salubrity. A full account should deal with the statutory as well as the legal aspects and describe the bonds that unite them. However, this section will deal only with the standards.

2.2.1 The Notion of "Standard"

In the field of asbestos, a standard represents more a threshold that should not be exceeded, than a safety guarantee. It is not a line which clearly separates good from bad but rather a maximum pollution tolerance.



Fibre sorting

The improvement of dust control in mills not only reduces the exposure in those plants but also has an important upgrading effect: asbestos delivered to manufacturers contains less fine dust.

Safety reforms did not immediately entail the use of standards. The Merewether report [2] developed a non mathematical heuristic approach in order to reduce the effects of asbestos on health. As epidemiological data and techniques were non existent at that time, no precise dust density standard could be established.

The advent of dust measuring equipment made possible weight analysis, monitoring and the establishment of quantitative standards. Monitoring consists in measuring the rate of dust concentration continuously and adopting necessary corrections whenever this rate exceeds the tolerance threshold. Its use in processing plants began at the end of the war, in England, and at the end of the '40s in Québec.

Ponderal analysis enabled searchers to determine dust standards up to the mid '60s, when new scientific knowledge inspired them to measure the pathogenic element itself, that is the microscopic fibre[1].

The quality of a standard, as far as its determination and its effects are concerned, thus depends on technical progress and epidemiological data. A technical innovation which increases the precision of measurements will have a positive effect on health, even if the standard does not vary. However, a lowering of the standard, with the same measuring apparatus, does not offer any guarantee of effectiveness. According to present day technology, detection limits are set at 0,5 fibre per cubic centimeter. However, at this level, the margin of error is very wide.

Epidemiological studies and medical knowledge form the theoretical basis for the standards system. They have contributed to differentiating the risk which different types of asbestos represent[2]. They also make it possible to project the benefits of lowering a standard. But the real incidence of this change is difficult to define. Thus in 1969, England justified establishment of the dust concentration standard at 2 fibres per cubic centimeter by an expected drop in the incidence of pulmonary diseases to a rate of 1%. However, because of the latency of asbestosis effects, one cannot yet measure the results of this standard. Since that time, the importance related to lung ailments has diminished and the aims of the standards seem vaguer and less "objective".

2.2.2 Current Standards

Appendix 1 shows the more and more exacting constraints set by the standards established in many industrialized countries in recent years. The lack of consensus is obvious, indicating the importance of political considerations and scientific controversy. However, it must be noted that technical improvements have reduced dust rates well within the standards in the majority of workstations throughout the whole industry.

1. Through the membrane filter technique, with fibre counting by means of a phase contrast microscope.
2. Among industrialized countries, only the United States do not recognize these differences.

3. CONSIDERATIONS AND CONSTRAINTS

3.1 Considerations for Producers

Rapid and ill justified changes in standards create such instability that they threaten the long term survival of mining operations. It is difficult to ensure long term development when adapting to the rapid lowering of standards. Cost (immobilization costs, development of deposits) and time constraints limit the flexibility margin of the primary producer. Furthermore, the recent recession undermines the financial health of firms. To survive, they have to deal with a stable environment.

To ensure their efficiency, mining producers may seek to integrate vertically. This strategy frees them from the uncertainties of the primary sector. If they cannot control their situation, they risk skimming their deposit and withdrawing from the market unless external socio-economical constraints hold them back.

The stabilization of standards at achievable technical levels is an essential condition of survival for the asbestos extraction industry. Without that stability, it appears that only socio-economical constraints could keep producers in business, in a more or less artificial manner.

3.2 Considerations for Manufacturers

The imposition of standards in the case of a product which has non regulated substitutes places manufacturers at a disadvantage. This onus must be compensated for by other advantages: economical (sale price, stability of supplies, amortization of additional capital) or strategical (possibilities offered by various markets). None of these compensation factors is in itself guaranteed in advance. The stability of supplies is never assured, even in times of prosperity. Non captive markets have been destabilized by long producers' strikes. The price difference which favored asbestos over its substitutes has decreased.

The uncertainty which surrounds the evolution of standards and the mitigated support from asbestos defenders prompt manufacturers to seriously consider using asbestos substitutes.

3.3 Considerations for the State

In the final instance, any private enterprise, no matter the extent of its social preoccupations, is governed by profitability. When the interests of an enterprise do not coincide with that of a society, the government — which represents this society — regulates the activities of the enterprise. The State also protects the interest of this society against other states.

To achieve this, the State must try to be objective. In the case of asbestos, it may prove this concern by assessing the risks presented by this mineral on human health scientifically. It must take into account the limits of simple models and weigh the alternatives. The director of the United States Environment Protection Agency, Mr. William Ruckleshaus, has stated that nothing undermines public credibility of a government agency as much as the introduction of political considerations in the evaluation of the risks presented by a substance.

CONCLUSION

It is currently recognized that conditions which prevailed in the utilization of asbestos until the beginning of the '50s, have been damaging to the workers' health. Scientific data on this subjet are eloquent, but the cases studied reflect a situation where the concentration of fibres in the air was much higher than permitted by current standards. The long term effect of exposure to current level and that of the '60s is not well known. However, a marked drop in the number of new cases of asbestosis is occurring in Québec. Dr. Edward Gaensler [70] declares that he has not encountered new cases in the last 2 or 3 years at his medical centre in Boston. In England, the number of deaths where asbestosis is mentioned is also dropping [71].

Scientific data, although incomplete, seem to indicate that the asbestos problem is diminishing. But the ban on asbestos will not eliminate it from the air because this mineral constitutes an important element of the earth's crust. The complete disappearance of the asbestos industry could therefore not guarantee any benefit to the population, on the contrary. Substitute fibres do not alter the quantity of asbestos in the biosphere and, besided, they present an additional risk which has yet to be fully appraised.

The analysis of the poor health conditions of the past provokes emotion, but subjective evaluation of the risks presented by asbestos in the past can distract from reality and lead to incorrect decisions. An objective assessment of the present must be made first. Nothing can lead to the conclusion that prevailing conditions in the asbestos industry imply a risk sufficient to justify the establishment of much stricter standards. Likewise, nothing leads to the belief that massive introduction of substitute fibres does not represent a danger. These fibres are biologically active [59, 63, 65, 66, 67].

Epidemiological surveys suffer from many limitations. Their representation of reality necessarily constitutes a simplification. Therefore, the hypotheses considered in the projections do not have a solid basis and they only constitute somewhat intuitive approaches.

Industrially exploited for the last century, asbestos is a known and proven product. Producers and consumers have learned how to use this mineral and have reduced the risks it presents for human health to an insignificant level. Of recent origin, substitute fibres are hardly known. But it is recognized that most of them have the same type of physiological effect as asbestos. However, in most user countries, there is no restriction on their use. Therefore, their utilization can have negative health effects.

Technical progress made in dust control allows us to foresee other improvements in salubrity in the next ten years. Handled with care, asbestos still has its place in the mineral industry.

APPENDIX 1

Standards Concerning Chrysotile in Fixed Workplaces

West Germany
1973: 0,15 mg/m^3 with chrysotile alone
4,0 mg/m^3 if mixed
1976: 2 fibres/cc
1983*: Limit set at 1 fibre/cc

England
1960: 177 asbestos particles per cubic centimetre
1968: 2-7 fibres/cc
1969: 2 fibres/cc; limit set at 12 fibres/cc
1983*: Limit set at 1 fibre/cc
1983: Limit set at 0,5 fibre/cc

United States
1959: Recommendation: 177 particles/cc
1965: 10 fibres/cc
1972: 5 fibres/cc; limit set at 10 fibres/cc
1976: 2 fibres/cc; limit set at 10 fibres/cc
1983: Proposed: 0,5 fibre/cc

* This standard was proposed by the EEC's Council of Labour and Social Affairs to member countries.

***Note:** In 1979, standards in other producing countries were as follows:*
— Australia 4 fibres/cc
— Finland 5 fibres/cc
— South Africa 2 fibres/cc
— U.S.S.R. 2 mg/m^3

APPENDIX 2

A Few Physico-Chemical Characteristics of Chrysotile Fibres

The quality of the fibre most sought after in the industry depends on its surface area. Industrial applications of asbestos require a maximum length of fibre for a minimal diameter. Thus asbestos goes through a defibration process which consists in separating bunches of fibres lengthwise, that is subdividing them into microfibrils. This subdivision increases drastically the surface area of the fibres. When it comes out of the processing plant, a gamme of chrysotile has a surface area of approximately 3 square meters. The quality of defibration is thus measured according to the ratio between the surface area and the weight of the fibre.

This high subdivision of fibres into micro-fibrils produces a significant release of fibres in the air. Fibres thus released, which have no real commercial value, can have a negative effect on health.

The harmfulness of asbestos fibres depends on properties related to their surface area. Their aerodynamic characteristics influence their deposition in the alveoli. But mostly, their surface has electrical properties which determine the amplitude of the body's reaction.

The zeta potential (measure of electrical surface charges) of chrysotile is highly positive under normal physiological conditions, therefore producing two consequences whose relative importance has not been entirely clarified.

Firstly, the lytic activity of chrysotile depends on the pH of the solution. This relation shows the importance of surface charges in the alteration of cells. This phenomenon is intuitively perceived, since the cell must maintain an ionic balance; disturbance of this balance can lead to the 'loss' of cellular elements.

Secondly, the surface charge of chrysotile determines the type of compounds for which it has most affinity. A negative surface tends to adsorb positive substances (cations) whereas a positive surface easily adsorbs negative substances (anions). However, one of the substances easily adsorbed by chrysotile is benzo-a-pyrene, a combustion residue of cigarettes. It is considered as the most likely agent to induce lung cancer among smokers. Thus chrysotile would increase the actual level of this substance in the lungs.

A surface alteration such as phosphorylation by phosphorus chloroxyde ($POC1_3$) brings the zeta potential closer to neutrality and radically modifies the physico-chemical properties of the fibre. The resultant product, chryso-phosphate (phosphated chrysotile), does not adsorb benzo-a-pyrene anymore, thus considerably reducing the risk of cancer.

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